REMARKS

Claims 1-9 and 11-30 are pending in this application. Claims 1, 14 and 17 have been amended. No new matter has been added.

Claims 1-6, 9, 11-13, 15, 16, 17-20, 23-27, 29 and 30 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Jiang et al. (U.S. Pub. No. US 2002/0009880 A1) ("Jiang") in view of Lopatin et al. (U.S. Patent No. 6,368,954 B1) ("Lopatin") and Applicant's Admitted Prior Art ("Prior Art"). This rejection is respectfully traversed.

The claimed invention relates to a method of forming a copper damascene structure. As such, amended independent claim 1 recites a "method of forming a copper damascene structure" by *inter alia* "patterning a low-dielectric constant layer to form at least one opening" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions." Amended independent claim 1 further recites "providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition."

Amended independent claim 14 recites a "method of forming a copper damascene structure" by *inter alia* "patterning a low-dielectric constant layer to form at least one opening through said low-dielectric constant layer" and "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions." Amended independent claim 14 further recites "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "subsequently providing a copper layer in said at least one opening . . . by contact displacement copper deposition at room temperature." Amended independent claim 17 recites a "method of forming a copper damascene structure" by *inter alia* "forming a material layer of methylsilsequiazane over a substrate; forming at least one opening through said methylsilsequiazane layer" and "forming a tungsten nitride layer by

atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening." Amended independent claim 17 also recites "subsequently removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer" and "providing a copper layer in said at least one opening."

Jiang relates to a "copper interconnect having a barrier layer (106, 206)." (Abstract). According to Jiang, the barrier layer is "a silicon containing metal barrier layer." (¶ [0006] at lines 1-2). Jiang emphasizes that the "silicon containing diffusion barrier 206 has low resistance and excellent wettability to Cu and to dielectrics such as FSG." Jiang teaches that "[c]opper is then deposited over the silicon containing barrier layer." (¶ [0006] at lines 6-7).

Lopatin relates to a copper interconnect using atomic layer deposition. (Title; Abstract). According to Lopatin, the interconnect structure has "a barrier layer formed over a patterned semiconductor substrate using atomic layer deposition; a pre-seed layer formed using atomic layer epitaxy; a thick seed layer; a bulk copper interconnect layer; and a top sealing layer." (Col. 3, lines 25-30). Lopatin teaches the steps of "depositing a layer of barrier material over said surface using atomic layer deposition; depositing a pre-seed layer of conducting material using atomic layer epitaxy; depositing a seed layer of conducting material" and "depositing a bulk interconnect layer." (Col. 3, lines 30-37).

The subject matter of claims 1-6, 9, 11-13, 15, 16, 17-20, 23-27, 29 and 30 would not have been obvious over Jiang in view of Lopatin and the Prior Art. Specifically, the Office Action fails to establish a *prima facie* case of obviousness. Courts have generally recognized that a showing of a *prima facie* case of obviousness necessitates three requirements: (i) some suggestion or motivation, either in the references themselves or in the knowledge of a person of ordinary skill in the art, to modify the reference or combine the reference teachings; (ii) a reasonable expectation of success; and (iii) the prior art references must teach or suggest all claim limitations. See e.g., In re Dembiczak, 175 F.3d 994, 50 U.S.P.Q.2d 1614 (Fed. Cir. 1999); In re Rouffet, 149 F.3d 1350, 1355, 47

U.S.P.Q.2d 1453, 1456 (Fed. Cir. 1998); Pro-Mold & Tool Co. v. Great Lakes Plastics, Inc., 75 F.3d 1568, 1573, 37 U.S.P.Q.2d 1626, 1630 (Fed. Cir. 1996).

First, not all limitations of amended independent claims 1, 14 and 17 are taught or suggested by the prior art, whether considered alone or in combination. None of Jiang, Lopatin and the Prior Art, considered alone or in combination, teaches or suggests "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions*" and "providing a copper layer . . . *selectively deposited by low-temperature metal-organic chemical vapor deposition*," as amended independent claim 1 recites (emphasis added). The prior art references also fail to teach or suggest "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "subsequently providing a copper layer . . . formed by contact displacement copper deposition at room temperature," as amended independent claim 14 recites. The prior art references further do not teach or suggest "forming a material layer of methylsilsequiazane over a substrate," "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions*" and "*removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer*" and "subsequently providing a copper layer in said at least one opening," as amended independent claim 17 recites (emphasis added).

As noted above, Jiang relates to "a silicon containing metal barrier layer" (¶[0006] at lines 1-2), and not to "a tungsten nitride layer," much less to the formation of "a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," as amended independent claims 1, 14 and 17 recite. Jiang also fails to teach or suggest "removing horizontal portions of said tungsten nitride layer" above a surface of the dielectric layer and "*subsequently* providing a copper layer in said at least one opening," as amended independent claims 14 and 17 recite. Jiang specifically teaches that "a copper layer 110 is formed on the barrier layer 206" and that the "copper layer 110 *and* barrier layer 206 are then removed back." (¶ [0033] at lines 1-2; Figure 4D; ¶ [0034] at lines 1-

2; Figure 3) (emphasis added). Thus, Jiang teaches that the copper layer 110, which would arguably correspond to the copper layer of the claimed invention, is provided prior to the chemical mechanical polishing process and not "subsequent" to it, as in the claimed invention.

Similarly, Lopatin fails to teach or suggest "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," as amended independent claims 1, 14 and 17 recite. Lopatin also fail to teach or suggest "providing a copper layer . . . selectively deposited by *low-temperature metal-organic chemical vapor deposition*," as amended independent claim 1 recites (emphasis added). In Lopatin, the pre-seed layer of conducting material is formed over the barrier layer using atomic layer epitaxy, and not selective deposition by low-temperature metal-organic chemical vapor deposition, as in the claimed invention. (Col. 3, lines 30-37). Lopatin also fail to teach or suggest "removing horizontal portions of said tungsten nitride layer" above a surface of the dielectric layer and "*subsequently* providing a copper layer in said at least one opening," as amended independent claims 14 and 17 recite. As clearly illustrated in Figures 5-9 of Lopatin, the removal of any horizontal portions of the barrier layer 401, which would arguably correspond to the tungsten nitride layer of the claimed invention, occurs only *subsequent to* the copper deposition, and not *prior to* it, as in the claimed invention. Further, the Prior Art fails to teach or suggest all limitations of amended independent claims 1, 14 and 17.

Second, a person skilled in the art would not have been motivated to combine the teachings of Jiang with those of Lopatin, as the Examiner asserts. The crux of Jiang is the formation of a "a silicon containing metal barrier layer" by a specific co-deposition method which "gives total flexibility of the Si concentration in the barrier film 106." (¶ [0006] at lines 1-2; ¶ [0021]). Jiang specifies that the "method for forming the silicon containing barrier is an in-situ process that allows higher throughput than ex-situ process." (¶[0022]). In contrast, the crux of Lopatin is the formation of a copper interconnect by atomic layer deposition. For this, Lopatin teaches the formation of tungsten nitride barrier layer 401 by atomic layer deposition and of the pre-seed layer 402 by atomic layer epitaxy.

(Col. 5, lines 29-43). Thus, one skilled in the art would not have been motivated to combine Lopatin, which teaches the formation of barrier and copper layers by *ex-situ* atomic layer deposition and epitaxy processes, with Jiang, which teaches the formation of barrier and copper layers by an *in-situ* process. For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 1-6, 9, 11-13, 15, 16, 17-20, 23-27, 29 and 30 is respectfully requested.

Claims 7, 8, 21 and 22 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Jiang in view of Lopatin, the Prior Art and Farrar (U.S. Pub. No. US 2002/0048931 A1). This rejection is respectfully traversed.

Claims 7 and 8 depend on amended independent claim 1 and recite that the low-dielectric constant layer "is formed by spin coating to a thickness of about 2,000 to 50,000 Angstroms" (claim 7) and "to a thickness of about 5,000 to 20,000 Angstroms" (claim 8). Claims 21 and 22 depend on amended independent claim 17 and recite that the methylsilsequiazane layer "is formed by spin coating to a thickness of about 2,000 to 50,000 Angstroms" (claim 21) and "to a thickness of about 5,000 to 20,000 Angstroms" (claim 22).

Farrar relates to a "damascene structure with a plurality of low dielectric constant insulating layers acting as etch stops." (Abstract). According to Farrar, the low dielectric constant materials "have similar methods of formation and similar capacities to withstand physical and thermal stress" and "act as insulating layers through which trenches and vias are formed." (Abstract). Farrar also teaches barrier layer 72 formed of "metals, such as titanium (Ti), zirconium (Zr), tungsten (W), or hafnium (Hf), or metal compounds, such as tantalum nitride (TaN) or silicon nitride (Si_3N_4)." (¶ [0046] at lines 1-4).

The subject matter of claims 7, 8, 21 and 22 would not have been obvious over Jiang in view of Lopatin, the Prior Art and Farrar. The Office Action fails again to establish a *prima facie* case of obviousness. Jiang, Lopatin, the Prior Art and Farrar, whether

considered alone or in combination, fail to teach or suggest all limitations of amended independent claims 1 and 17, and of dependent claims 7, 8, 21 and 22.

None of the cited prior art references teaches or suggests "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions*" and "providing a copper layer . . . selectively deposited by *low-temperature metal-organic chemical vapor deposition*," as amended independent claim 1 recites (emphasis added). Jiang, Lopatin and the Prior Art also fail to teach or suggest "forming a material layer of methylsilsequiazane over a substrate" and "forming at least one opening through said methylsilsequiazane layer," "forming *a tungsten nitride layer by atomic-layer deposition using sequential surface reactions*," "removing horizontal portions of said tungsten nitride layer formed above of a surface of said methylsilsequiazane layer" and "subsequently providing a copper layer in said at least one opening," as amended independent claim 17 recites (emphasis added).

Similarly, Farrar teaches that "the barrier layer 72 is simultaneously deposited in both the via 65 and the trench 67" (¶ [0047] at lines 2-6) and that "*a conductive material 80 is next deposited* to fill in both the via 65 and the trench 67." (¶ [0048] at lines 1-2) (emphasis added). Accordingly, Farrar is entirely silent about "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer," much less about "*subsequently* providing a copper layer in said at least one opening," as amended independent claim 17 recites (emphasis added). For at least these reasons, the Office Action fails to establish a prima facie case of obviousness and withdrawal of the rejection of claims 7, 8, 21 and 22 is respectfully requested.

Claims 14 and 28 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Jiang in view of Lopatin, the Prior Art and Gross (U.S. Patent No. 6,380,083 B1) ("Gross"). This rejection is respectfully traversed.

Gross relates to a "process for fabricating a semiconductor device with copper interconnects." (Abstract). According to Gross, "a layer of dielectric material is formed on a substrate" and a "barrier layer to prevent copper diffusion is then deposited over the

entire surface of the substrate." (Abstract). Gross teaches that a "dual copper layer is formed on the barrier layer." (Abstract). Gross further teaches that "one layer is deposited using a vapor deposition technique such as chemical vapor deposition (CVD) or plasma vapor deposition (PVD)" and that the "other layer is deposited by electroplating." (Col. 2, lines 47-50).

The subject matter of amended independent claims 14 and dependent claim 28 would not have been obvious over Jiang in view of Lopatin, the Prior Art and Gross. None of the cited references teaches or suggest "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions," "removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing" and "subsequently providing a copper layer in said at least one opening . . . by contact displacement copper deposition at room temperature," as amended independent claim 14 recites. The cited references also fail to teach or suggest "forming a material layer of methylsilsequiazane over a substrate," "forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions" and "subsequently removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer," as amended independent claim 17 recites.

In addition, Gross teaches away from the claimed method.[1] Gross discloses that although "[e]lectroless metal deposition (i.e., electroless plating) has been investigated as a technique for depositing copper onto a patterned layer of dielectric material . . . the surfaces to be plated . . . must be pretreated before the metal is deposited in order to effect electroless deposition." (Col. 2, lines 11-17). Therefore, according to Gross, low deposition rates and issues of bath stability "*make this approach unattractive* for use in production." (Col. 2, lines 17-18). In contrast, amended independent claim 14 recites "subsequently providing a copper layer in said at least one opening . . . *by contact*

[1] In accordance with M.P.E.P. § 2144.05.III, a *prima facie* case of obviousness may be rebutted by showing that a reference, *in any material respect*, teaches away from the claimed invention. M.P.E.P. § 2144.05.III (2001) (emphasis added), citing In re Geisler, 116 F.3d 1465, 1471, 43 U.S.P.Q.2d 1362, 1366 (Fed. Cir. 1997). "A prior art reference that 'teaches away' from the claimed invention is a significant factor to be considered in determining obviousness." M.P.E.P. § 2145.X.*D*.1 (2001).

displacement copper deposition at room temperature" (emphasis added). In this respect, Gross *teaches away* from the claimed invention. Accordingly, Gross is an improper reference for the rejection of amended independent claim 14 as being unpatentable under 35 U.S.C. §103(a). For at least these reasons, the Office Action fails to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 14 and 28 is respectfully requested.

A marked-up version of the changes made to the specification and claims by the current amendment is attached. The attached page is captioned "**Version with markings to show changes made.**"

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to withdraw the outstanding rejection of the claims and to pass this application to issue.

Dated: January 29, 2003

Respectfully submitted,

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Version With Markings to Show Changes Made

1. (Twice amended) A method of forming a copper damascene structure, said method comprising the steps of:

patterning a low-dielectric constant layer to form at least one opening through said low-dielectric constant layer;

forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening; and

providing a copper layer in said at least one opening and in contact with said tungsten nitride layer, wherein said copper layer is selectively deposited by low-temperature metal-organic chemical vapor deposition.

14. (Twice amended) A method of forming a copper damascene structure, said method comprising the steps of:

patterning a low-dielectric constant layer to form at least one opening through said low-dielectric constant layer;

forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening; [and]

removing horizontal portions of said tungsten nitride layer formed above a surface of said low-dielectric constant layer by chemical mechanical polishing; and

subsequently providing a copper layer in said at least one opening, wherein said copper layer is formed by [electroless deposition] contact displacement copper deposition at room temperature.

17. (Amended) A method of forming a copper damascene structure, said method comprising the steps of:

forming a material layer of methylsilsequiazane over a substrate;

forming at least one opening through said methylsilsequiazane layer;

forming a tungsten nitride layer by atomic-layer deposition using sequential surface reactions, said tungsten nitride layer being in contact with said at least one opening; [and]

removing horizontal portions of said tungsten nitride layer formed above a surface of said methylsilsequiazane layer; and

subsequently providing a copper layer in said at least one opening.